THE USE OF IN-SITU GERMANIUM GAMMA SPECTROSCOPY TO FIND, IDENTIFY, LOCALIZE, AND QUANTIFY HIDDEN RADIOACTIVITY

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ABSTRACT

Radiological characterization in DD & ER projects is an important part of the project. When properly applied it can provide much needed information to better plan the project, to guide the progress of the remediation, to know when to stop remediating, and to prove officially that the job is complete. One of the more expensive radiological characterization tasks is the location and quantification of hidden or buried sources. Many samples must normally be taken for laboratory analysis, which is costly and takes much time. With the newly available InSitu gamma spectroscopy systems, this can often be done in the field. InSitu gamma spectroscopy avoids the dose and industrial hazard of extracting samples, avoids the necessity of packaging and transporting to fixed laboratories, gives results nearly immediately, and generates no waste. Reactors facilities [operating or shut down], Uranium processing facilities, NORM contamination sites, and weapons sites all have nuclides that are amenable to InSitu Ge gamma spectroscopy. Applications include locating and quantifying surface contamination on floors and walls; locating and quantifying subsurface items like pipes and drums; determining the fill height and activity inside closed containers like drums, boxes, and pipes; and determining the activity-depth profile of neutron-activation without taking samples. The key to determining the location of radionuclides is the variation of the radioactive emissions as a function of energy, distance, angle, absorber material, absorber thickness. Measurements at different energies, angles, distances from an object, when analyzed as a group can tell the location of the radioactivity within the object. To make this process convenient and practical, fast and accurate mathematical efficiency calibration tools are needed. The efficiency calibration software supplied with the Canberra ISOCS system is one such method. Multiple calibrations are made quickly with the software to determine the efficiency variation for each of the multiple energy lines and/or measurements of the object. The correct source location can be determined by iterative manual computations, by large numbers or random computations, or by matrix analysis methods.

INTRODUCTION

Radiological characterization is an ongoing process at DD/ER projects. It must first be done to plan the project. Then it must be done to monitor the progress of the project. Finally, it must be done to prove that the project is successfully completed. While it is relatively easy to find things on the surface of a wall or soil, the DD/ER project manager must also be concerned with things that are not on the surface, and hidden from the conventional detection techniques. The current practice to evaluate hidden (buried or covered) radioactivity is to extract a large number of samples, package the samples, transport to the analysis laboratory, prepare the sample for assay, count it, and then report the data. This process has many flaws. The obvious one is that since the actual location of the activity is not well known, and not likely to homogeneous, there is a low probability of any sampling strategy to find the radioactivity. And, since the activity of the item or material is unknown, any samples must be extracted with appropriate radiological safety conditions, which adds extra manpower and reduces worker efficiency. The sample extraction method may be difficult [e.g. concrete, steel pipes], and usually involves risk of injury. The process of taking the sample, sending it to the lab, counting it, and analyzing the data takes time, generally days or weeks, which adds to the cost of a dynamic process like D&D or ER. And, what is subsequently analyzed by the laboratory is a very small part of the item to be assessed. Since in most cases the distribution of radioactivity is non-uniform, the representativeness of this small sample is usually in doubt.

Today’s technology includes: large Ge detectors; reliable and portable cryostats; small digital battery operated MCAs; powerful laptop computers; good quality gamma spectroscopy software; and now with the introduction of Canberra’s ISOCS system, also includes accurate, versatile, and fast mathematical efficiency calibration software. This combination makes in-situ gamma spectroscopy a very practical tool to use for DD and ER applications, and in
many cases, more practical than sampling and laboratory analysis. InSitu gamma spectroscopy should be strongly considered for those cases where laboratory gamma spectroscopy is an acceptable analysis technique. This would include Uranium contamination sites, and Reactor contamination sites. Plutonium, and other research sites in certain cases may also be suitable as long as the difficult-to-measure nuclides are high enough in activity [e.g. those with low yield and/or low energy gammas] or where those nuclides are correlated with other easier-to-measure nuclides.

Contrast the problems of conventional methods using field gross-counting measurements and sampling to Germanium in-situ gamma spectroscopy. Because gammas penetrate significant distances in soil, concrete, or air, contamination can in most cases be measured in place. Therefore there is no labor and risk and lost time from the sample-taking process. Because a very large portion of the item, or even the entire item is measured, the sampling errors are greatly reduced. The large sample size also improves the detectability and reduces the measurement time. Non-uniformity is still a potential problem, but can be addressed by multiple measurements of the object or area. Germanium detectors allow easy and accurate identification of the nuclides, and separation of natural radioactivity from that which may have been added by the site. Mathematical efficiency calibrations allow very quick efficiency calibrations in the field, even during the sample acquisition time. Consequently, accurate and quick results are generated in the field. These results may be used to guide the next set of measurements, and for immediate feedback to the work crew [e.g. stop the decontamination process, or change to a less aggressive process]. Germanium in-situ measurements can also be effectively used to provide site-specific calibrations for gross-counting measurement instruments, as those devices, especially alpha/beta counters, are very sensitive to the many changing field conditions in DD/ER projects.

In a DD and ER project there are many questions that must be answered via site characterization. Is any activity there? Where is it? How much? How deep so that we can figure out the optimum remediation method? Have we missed any that might be hidden behind the floor/wall, in buried piping, seeped through cracks in the floor, up in the ceiling, etc.

The combination of quick and accurate mathematical efficiency calibrations and large sensitive Ge detectors allows more than just activity to be determined. It also allows reliable source location information to be obtained, and/or the distribution of the radioactivity within the source. Sometimes just a single measurement is needed, but more often multiple measurements and multiple gamma energies are combined for easier and better results.

**BASIS OF THE METHOD**

Determining the location of the radioactivity using in-situ techniques depends upon differential radiation intensity at the detector as a function of:

- distance from the source;
- angle of the detector to the source, especially when collimated;
- attenuation from items between the source and the detector;
- energy of the gamma ray used for activity determinations.

Under perfect conditions, e.g. in a laboratory when counting a prepared sample, all of the parameters of size, density, source uniformity, and source location are known, and determining the efficiency and then activity is a simple task. But, for in-situ measurements, it is common for several of the dimensions or other parameters to be unknown. Therefore, we must use additional information from a single or multiple source measurements to determine the unknowns.

Using the principles enumerated above, either separately or in combination, allows the location and size of the source to be determined, along with the activity of the source. In principle, one creates a model of the hypothetical source, including all attenuating materials and the geometric relationship to the detector. Then, using the ISOCES efficiency calibration method, or any other reliable method, an efficiency vs. energy calibration is obtained. The unknown parameters are determined by evaluating the activity at multiple energies, if the radionuclide has multiple gammas that can be detected, and/or by making multiple measurements of the item from different distances, directions, or under different collimator conditions. An efficiency calibration is done for each of these measurement conditions. The gamma spectra obtained under each of the measurement conditions is then analyzed and the results
computed for each energy of each nuclide. The set of results are evaluated. The correct solution will show that all energies of the same nuclide have the same activity, and that all measurements of the same source under different conditions of direction/distance/collimation have the same activity. This will only happen when all of the efficiency calibrations are correct. The correct efficiency calibration will only happen when all of the items affecting efficiency are correctly included in the efficiency calibration computer model or calibration apparatus. Such items include distance, size, density, covering material, source uniformity, etc. This will only happen when the hypothetical source used in the calibration model adequately mimics the real source being measured.

INSITU GE GAMMA SPECTROSCOPY AND THE ISOCS MATHEMATICAL EFFICIENCY CALIBRATION

While these principles may be applied generically, it is this new technology in the past few years that makes it practical. Gamma Spectroscopy allows the effect of attenuation at various energies to be used. Small portable high quality battery operated MCAs and Laptop PCs now make this practical for field use. Ge detectors [as compared to NaI detectors] have very good energy resolution, and therefore allow simple and reliable spectral interpretation, and excellent ability to differentiate the energies from the nuclides of interest from the naturally occurring Radium/Thorium/Potassium in the environment. Large Ge detectors are now available for shorter count times and better statistics. Detectors can be pointed in all directions, while still keeping cool for 5 days with modern LN cryostats. Special shielding and collimation is available to allow various counting conditions to be easily configured in the field from a few basic components. All of these things make InSitu gamma spectral acquisition and nuclide identification now quite practical around a DD/ER project site. But, for nuclide quantification, accurate efficiency calibration is necessary.

Efficiency calibrations are traditionally done by first constructing a realistic approximation of the sample with known radioactive sources. While convenient in the laboratory, it becomes quite impractical for large or complicated objects. The new ISOCS mathematical efficiency calibration software allows the user to construct mathematical models, rather than physical models with radioactive sources. This gives accurate efficiency calibration results very quickly and economically. And, the wide variety of source geometry templates and the many variations within each of these templates allows many different source conditions to be modeled and therefore calibrated.

Features that can be varied in the ISOCS software templates include the following [not all features on all templates]:

- Distance between source and detector
- Horizontal offset between the axis of the source and the axis of the detector
- Angular differences between axis of the source and the axis of the detector
- Thickness, composition, and density of multiple attenuators between the source and the detector
- Collimation [attenuate with a conical or trapezoidal hole ] between the source and the detector
- Distribution of radioactivity within the object
  - Multiple source layers with different composition and concentration within each source layer
  - Multiple source volumes, e.g. hotspot simulation
  - Dual exponential [rising then falling] distribution of radioactivity within a source layer

By varying these features, and evaluating the detector’s response at various energies, from various distances and angles, and with various collimators, a reasonably accurate estimate of the location and the activity of the object can be made.

So, now, the DD/ER project manager can use this relatively new tool to help him plan the project better, monitor the progress of the decontamination, and better define when it is done.
ILLUSTRATIVE EXAMPLES

Locating and Quantifying Sources Near to the Surface of a Floor or Wall

The most common field radiation measurements in DD/ER applications are done simply to find radioactivity. These are rarely accurate estimates of the activity or concentration, but just indications of abnormalities. Examples are looking for hot spots in the soil surface with gross counting NaI detectors, or using multiple or position sensitive beta detectors to look at floor or wall surfaces. If elevated activity is found, it is generally removed, rather than quantified and compared to a limit. These techniques involve taking a large number of measurements on very closely spaced “grids”. Because the detectors are close to the surface, and in addition since they are commonly beta-sensitive detectors, they only detect radiation that present immediately in front of the detector. That is good if the task is to accurately locate the position of activity on the surface, and if the survey method assures 100% coverage of the potentially contaminated surfaces. To save labor there are numerous devices that combine position sensing [GPS, encoders, ultrasonics] with radiation detection and quickly store the data and display maps of the area surveyed. These types of devices are surely part of every DD/ER project.

But, if the task also requires nuclide identification and accurate quantification, then InSitu gamma spectroscopy can help refine the measurement data. Beta detection calibration factors are highly sensitive to the nuclide being measured [beta yield, energy], and highly sensitive to any absorbers between the source and the detector [dirt, paint, absorption into the ground/concrete/wood]. So any field conditions that make these parameters different than what was used to develop the calibration factors will affect the accuracy of any quantification. A valuable use of InSitu gamma spectroscopy is to develop site-specific calibration factors for these beta detection instruments. The positional information from their surveys can be used to define the calibration model for the Ge InSitu detector. Analyzing the spectrum will then give nuclides and activities. From several of these measurements, it can be determined if the field conditions are constant, and if so, a calibration factor and uncertainty estimate in the calibration factor can be developed. This process would be repeated whenever field conditions change.

NaI detectors are normally used to count gamma-emitting sources, which makes them less sensitive to small variations in coverings, but, since the detector is very close to the surface [for good sensitivity and spatial accuracy] it is still heavily impacted by inverse-square-law effects, and can miss small sized sources unless very close to them. And, since they are gross counting devices, the calibration factor is still dependent upon the nuclide [gamma yield, energy]. InSitu gamma spectroscopy can be used to improve these measurements also. Site-specific nuclide ratios and calibration factors can be determined in the same manner as described above.

Localization and Quantification of Activity from Gridded Measurements

The above section discussed relatively easy measurements of small flat smooth easy-to-reach areas. But what about ceilings, high walls, rough surfaces, ground covered with brush or trees, rough ground. Those might be better addressed with gamma spectroscopy, which can be done at a distance where it is safer and easier. One simple way to localize and quantify the activity is to place collimation around the detector to define the field of view to a limited area. The ISOCS calibrations can handle most any collimator type with each of the various templates. Multiple such measurements can then be used to cover the entire ceiling, wall, or other surface. However this requires many different measurements to cover the entire surface.

A more efficient method would be to first take uncollimated measurements with fewer more widely spaced grid points. The spacing of the grid points must be close enough to allow overlapping fields of view, but without collimation this still is far fewer measurements than with collimation. These multiple measurements are then evaluated as a group. If all of the analyses from these overlapping broad area measurements show no detectable activity, then there is very good proof that the area is clean. This might solve most initial site characterization and final release survey characterization tasks, as most of those areas are likely to be clean. However, unlike the conventional measurements with beta detectors in close proximity to the surfaces, this array of broad area gamma measurements make it difficult to miss hidden activity, as long as it is sufficiently near the surface for the gammas to emerge. If the individual measurements in this grid all show the same amount of detectable activity for the relevant nuclide, then there is good proof that the source concentration is uniform. And, if a small grouping of the array shows elevated activity as compared to the rest of the grid points, then simple mapping techniques or software programs can define isopleths showing the location and relative magnitude of the activity. But, now that the activity
is known to be non-uniform, the uniform calibration that was probably used in the initial default spectral analysis is known to be incorrect, and therefore the activity measurements are not quite correct.

At this point, the user has 2 choices to refine the elevated activity measurements. He can add collimation to the detector, and perform another array of measurements using a finer grid to covering the areas of elevated activity. This gives more accurate positional information and more accurate activity results. Compared to the technique of doing collimated measurements over the entire area, this dual approach needs fewer measurements, and therefore less time. The process and data interpretation is quite straightforward and generates useable results immediately after the acquisition and spectrum analysis.

The second approach involves using mathematical analysis to better interpret the entire array of gridded measurements. Since some readings are higher than others, it is known that the default assumption of uniform activity distribution over the entire area is incorrect. For example, if there is a room ceiling size of 10 x 10 meters one might use 4 detector locations on the floor, and acquire the 4 spectra. For this type of geometry, the detector should be uncollimated, or only with shielding around the side an back of the detector [to minimize influence of floor contamination]. This allows each detector location to detect activity from the other grid locations, but with a different [lower] efficiency. That requirement for multiple overlapping fields of view is critical for this analysis technique. Mathematically divide the total area into smaller sized areas, e.g. 2m x 2m grid size. Calibrate each detector location for each source area. This means that if there are 4 detector locations and 25 source areas, there are 100 efficiency equations needed. However, the ISOCS mathematical process is quite fast, and there is much symmetry making many of the efficiency values the same. Next distribute hypothetical activity at various levels in each of the various source areas and compute an efficiency calibration each of the 4 detectors for each line of each nuclide found in the real spectrum. Analyze the 4 spectra with these 4 hypothetical efficiencies. Repeat this process for various hypothetical source distributions. The best distribution function is that which causes the best agreement between the 4 analysis results for all lines of all nuclides, when properly considering all uncertainties. This process could be done manually, if one has time and patience. There it is best done sequentially, evaluating the results from one hypothetical distribution to more accurately guess at the next distribution. But, this is clearly a place for computerized analysis. They could do it by brute force, computing a large number of hypothetical distributions, and selecting the best one of group. Or, a matrix reduction program could be used to find the best solution. However, unless the data is of extremely high quality [rarely possible in DD/ER applications] there are usually multiple solutions that look equally good [statistically speaking]. For DD/ER cases, one usually chooses the worst scenario that gives statistically acceptable results. An excellent implementation of the matrix approach is by Reginatto, et. al. [EML-590]. They used a “maximum entropy” solution to solve the matrix to find the worst possible distribution [most non-uniform]. This is not likely to be the true distribution, but if this worst case distribution meets regulatory compliance, then all other more likely distributions will also.

This field of automated mathematical analysis of groups of spectra from the same object is highly adaptable to computerized solutions, especially with the ISOCS mathematical efficiency calibration software, and is a fruitful area for future development.

Location and Quantification of Buried or Covered Sources

These same types of analysis techniques can be used to find the depth of a source, or the amount of absorber between the source and the detector. Practical applications include: contaminated soil covered by clean soil an/or concrete; buried contaminated pipes in walls, floors or soil; hot spot inside large waste container; lost sources in garbage trucks or landfills. The technique is easier if the nuclide contains multiple gamma energies, but also possible if the user is not so fortunate. In both cases, the spatial location and approximate lateral extent of the source must be first determined. This can be done various ways. Visual observation can sometimes be used. Non-radiological techniques may be used to find the locations of buried pipes. Or portable survey meters in a scanning or gridded mode can be used. Generally, a combination of several techniques is used.

Multiple energy nuclide example:

Some nuclides emit multiple gammas of various energies. When those gammas are of widely different energies, they undergo differing amounts of attenuation from absorbers in-between the source and the detector. Nuclides that are favorable here, and commonplace in DD/ER applications include:
Eu-152  long lived activation component in concrete, rocks, soils, insulation, aluminum
Cs-134  common fission product
Radium + daughters  natural nuclide that is sometimes technologically enhanced
Thorium + daughters  natural, sometimes technologically enhanced, wait ~10 y. if processed
U-238 + daughters  wait ~2 mo. if processed; better when enrichment is known
U-235  better at high activity
Pu-239  when at high activity

Note: for Ra, Th, and U, it is better to combine the various daughters into one “nuclide” as that gives more energy lines to use, and consequently more power to the algorithm.

After finding the location of the source, place the Ge InSitu detector near the source and count long enough to get good statistics for the various nuclide lines. Now, take your best guess as to the hypothetical location of the source. Use this guess and other known data [source size, absorber composition and density, etc.] and the ISOCS mathematical efficiency calibration software to compute the efficiency. Analyze the spectrum with this efficiency. Does the activity for all energy lines for the same nuclide agree? If so, your guessing is very good. If not, use the direction and magnitude of the disagreement to help better determine your next guess. Continue in this iterative approach until all lines are in statistical agreement. That is your best indicator of the correct answer. This process is rather quick, and can be done manually. But, it is easily automated, which might make sense for larger jobs with the repetitive measurements of the same type.

Single energy nuclide example:

Many other common nuclides have only a single gamma energy that is usable. Those include Cs-137 [x-ray generally too low energy], Co-60 [high energy gammas too close together], Am-241 [more gammas at very high activities], Zn-65 [annihilation gammas easily confused with many others], Mn-54. Now, since there is only one usable gamma energy, the depth information must be deduced from multiple measurements of the same object. Each measurement must be from a different location, where the location is selected to maximize the impact of the unknown values on the spectrum, but while still allowing the gammas to be detected with adequate statistics. If depth is the only unknown, then a minimum of 2 measurements are needed. If more items are not known, then more measurements are needed. And, the same iterative or automated approaches described earlier can be used. Guess at the depth [or other variable], compute the efficiency for each of the 2 [or more] measurement geometries, and then compute the activity for each of the spectra. If they all give the same activity, then the guess was very good. Otherwise continue in an iterative approach until they do. This can also be quite easily automated for larger jobs and/or quicker analysis results.

Location and Activity in a Sealed Container

Often, the user is presented with measurement scenarios where the exact location, size, shape, and/or density, of the source is not known, and where it is impractical to obtain it. Examples include drums or boxes of radioactive waste packaged long ago with inadequate records of fill height and density; tanks filled with radioactivity where height determination is hazardous; pipes with radioactivity where radioactivity might be in solution or plated out or precipitated out; boxes or drums with a few obvious hot-spots of elevated radioactivity.

The solution to these uses a combination of the same techniques previously discussed: perform multiple measurements from multiple detector locations and using multiple gamma energy activity values where possible. Hypothesize some various source conditions. Perform efficiency calibrations for each source condition for each detector location. Analyze each spectrum. The most correct source condition is the one where all the energy line activity results agree for each nuclide, for each detector, and where all the detector results agree for each nuclide. For simple cases, this can be manually performed, but where there are many measurements and multiple possible distributions, an automated procedure would make more sense.

A typical example is a 200 liter waste drum. It was filled many years ago. The contents were noted as “soil” but nothing else. The task is to find out the activity, but in order to do that the correct geometry must be known. This includes fill height and density, but which are not known. It is not desirable to open the drum and measure the fill height, but it can be weighed. If the nuclides inside include multi-line gamma emitters, just make one count with the
detector aiming toward the center of the side of the drum. With the ISOCS software, compute several efficiencies varying only the fill height and density so that the weight is correct. The correct model is the one where the multiple lines agree in activity. If only single gamma nuclides, then take 2 measurements, one with the detector toward the bottom of the drum, the other with the detector toward the top of the drum. Adjust the model density and fill height until both spectral analysis results give the same activity.

For Pipes, the activity could be in solution and distributed uniformly throughout the volume of the fluid, or the activity could be plated out and distributed along the inner surfaces of the pipe, or the activity could have precipitated or dried out and be along the bottom of a horizontal pipe. Perhaps survey meter scans around the perimeter of the pipe can see if there is excess activity on the horizontal surface and thus help interpret the data, but it can’t tell the difference between activity on the inner walls or in the fluid. But multiple measurements and multiple energy analyses can probably do it. The ISOCS Pipe model allows these three distributions of activity, and many other variables, if necessary. Note that in the cases of a fluid distribution and a wall distribution, both are symmetric. If the nuclide is not multi-energy, then all radial locations at the same distance will look the same. So, either the distance must be varied or the angle of a collimated detector must be varied in order to differentiate between these 2 cases. All of the ISOCS model templates accommodate these detector positions.

Distribution Profile of Neutron Activation in Concrete Wall or Fallout in Soil

There are many situations where the radioactivity is not uniformly distributed within the source region of an object. One example is concrete that has been exposed to neutrons. If the concrete is exposed to a flux of thermal neutrons, the entrance surface would have the highest activity, which would decrease exponentially as neutrons are absorbed and removed from the flux. If the concrete is exposed to a higher energy neutron flux, the activity will first be low [fast neutrons have lower cross-section than thermal ones, generally], and then it will rise [as the neutrons become thermalized] until it reaches a maximum and then decreases exponentially.

Other situations that cause this similar exponential decrease in activity with or without an increasing entrance segment include fallout on soil, ion exchange columns, and charcoal air filters for iodine or radon. When radionuclides are spilled on concrete or soil, they also tend to fit an exponential distribution after time. Single exponential distributions have been long used to describe the depth distribution of radio-cesium weapons testing fallout in soil. That type of distribution was fine as long as the deposition continued. However, once testing stopped and most of the atmosphere was depleted, input stopped. But rain continued which washed out upper layers moving the Cs-137 downward. This also created the double exponential distribution first rising then falling exponential. Simplistic algorithms that assume the maximum is at the surface will give incorrect activity results.

In DD/ER projects, the activated concrete must be treated in the least costly manner. Treating is all as radioactive waste is quite expensive, so commonly the more radioactive layers are removed. The same goes for soils or concrete contaminated by surface deposition of radioactive material. To plan this work, many core samples of concrete or soil are taken, which takes time and is somewhat dangerous. Then these cores are sliced in layers for laboratory analysis. Several months later the results are returned.

For the case of neutron activation in concrete, determining the depth distribution function non-invasively and quickly is rather easy because of the presence of trace amounts of europium in most all soils, rocks, and concrete. Since Eu-151 has an extremely high thermal neutron cross-section, and a relatively long half-life, the Eu-152 produced commonly the dominant nuclide after several years of activation and several years after the activation ceases. And, since Eu-152 has 6 or more high abundance gamma lines, both at low and high energies, it is the best example of a nuclide that is measurement-friendly. Normally just one measurement is needed, where the count time is long enough to give good statistics for the peaks. The detector is generally somewhat collimated to shield the back and sides of the detector from other radioactive items in the area, and may be collimated at the end to have a small field of view.

With InSitu spectroscopy and the ISOCS efficiency calibration software, it is quite data analysis easy and quick. Various efficiency calibrations representing hypothetical but realistic distributions are created. They are tested by comparing the computed activity of each of the many Eu-152 lines until they all give the same activity.
The original ISOCS software release allowed the user to model the activity vs. depth profile with a series of radioactive layers, where the thickness and concentration [and also material and density] could vary in each layer. This had a stair-step distribution, rather than a smooth continuous distribution but when used properly it worked quite well. However, since it was difficult to use properly and quickly, a new template was created and is now part of the ISOCS software. This template [exponential circular plane] has a single radioactive region covered by 2 absorbers. Within the radioactive region, the user defines the material, thickness, and density, and in addition specified 3 parameters to show the depth distribution profile. These 3 parameters are initial fractional relative concentration [number from 0 to 1], the depth at which the maximum concentration is reached, and the relaxation length of the exponentially decreasing fraction. Now, with just 3 variables [starting fraction, depth of maximum concentration, and decreasing relaxation length], most of these distributions can be easily defined. And since the number of variables is reduced, the problem is easier to solve. For small projects it is a quick manual process, but for large projects, this can easily be automated. The results are available in a matter of hours, rather than months.

For the cases where multi-energy nuclides are not available, e.g. Cs-137 in soil, a different process must be used. Since there are 3 variables to solve for, then at least 3 different measurements must be taken. They must be taken in such a manner as to have a significantly different energy response. Since fallout in soil is generally rather uniform laterally, simply moving the detector doesn’t do this. But, taking 3 or more differently collimated measurements does. These differently collimated measurements could be done various ways; e.g. 3 different sized opening apertures, 3 different collimated detector angles from the surface, 3 different diameter absorbers in front of the detector [inverse collimation]. Now, solving the equation for the parameters of the 3 unknown variables is possible, either the manual iterative process, or the mathematical method.

CONCLUSION

The new computerized modern tools and equipment that is now available for use have made InSitu Ge gamma spectroscopy a very versatile analytical technique. The prime tool that makes this practical for the typical user is the ISOCS mathematical efficiency calibration software. It can perform quick and accurate calibrations in the field without radioactive sources. The supplied templates cover a wide variety of sample shapes, detector configurations, and radioactivity distributions within the samples. The portable and shielded ISOCS measurement system allows the user to quickly take one or multiple measurements of an object or area. With the ISOCS software, the user can quickly mathematically compute the efficiency for various hypothetical source distributions. Then he can test which of these distribution is most nearly correct by comparison of the analysis results with other energy lines of the same nuclide, and with the same nuclide in other spectra. This will make DD/ER characterization tasks more economic and generate the results much more quickly than conventional techniques.

REFERENCE

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